

Meeting Summary  
North American Wellbore Integrity Workshop  
October 16-17, 2013 in Denver, CO

A lively meeting on problems and issues in managing wellbore integrity was held in Denver, CO. With new sponsorship by the Petroleum Technology Research Centre, the Wellbore Integrity working group expanded its scope beyond CO<sub>2</sub> sequestration to consider issues in hydraulic fracturing and geothermal energy. The workshop was organized around five primary areas: 1) Mechanics and chemistry of wellbore performance; 2) Design and construction; 3) Evaluation and testing; 4) Remediation; 5) Regulatory approaches; and 5) Case studies of field-scale performance.

Several speakers presented in-depth studies of well performance in wells from Pennsylvania, Texas, the Gulf of Mexico, and Alberta. These studies analyzed rates of failure, which included in a spirited discussion of the difference between a barrier failure (leakage through one component of a multi-barrier wellbore system) and well integrity failure (leakage that escapes the wellbore system with the potential to impact groundwater). A session on regulatory approaches included Canada, the US, and UK as examples. The latest research on geochemical and geomechanical processes in wells revealed new understanding of material performance and leakage potential. The workshop also included presentations on the effectiveness of monitoring approaches as well as methods of remediating leaking wells. Brief summaries of the presentations are as follows:

- Bob Welty (Schlumberger) kicked off the meeting with an informative overview of the state of the art of evaluating well integrity issues through the use of logging tools and simulations. The talk led to a discussion of whether too much emphasis is placed on cement bond logs versus other evaluation methods including direct pressure tests or review of cementing reports.
- Tony Ingraffea (Cornell University) described a new study of 41,000 well records in Pennsylvania drilled from 2000-2012 in which he analyzed rates of reported well integrity problems in conventional versus non-conventional wells. He found a greater rate of reported problems (by a factor of 6) in unconventional (shale gas) wells and distinct geographic influence on rates of reported well problems. A follow-on discussion highlighted the interpretation of reported problems compared with actual well failure, the regulatory environment particular to Pennsylvania, and the need to determine root causes of well leakage.
- Theresa Watson (Watson & Associates) spoke on the regulatory environment in Alberta, Canada. There are specific Directives aimed at hydraulic fracturing operations. There is a strong focus on problems arising from inter-well communication as when hydraulic fracturing in one well communicates with an older well in the field. New regulations for abandoning wells cap and *vent* rather than the simply capping, which was a practice that could lead to

excess pressure within the abandoned well. A discussion followed on the concept of what defines an acceptable leakage rate.

- Howard Loseth (Government of Saskatchewan) described Saskatchewan's approach to regulation of well integrity.
- James Craig (IEA Greenhouse Gas Programme) provided a very nice link to our previous affiliation with IEAGHG's Network. He described the UK's regulatory approach, including the very interestingly named "Department of Energy and Climate Change".
- Stuart Ellsworth (Colorado Oil and Gas Commission) gave a hands-on perspective of regulatory activities in Colorado. His view is that pressure is the key observational parameter and he argued for keeping the production annulus open to the surface. This generated an interesting discussion on the merits of this practice, with one downside being potential corrosion issues on the exposed casing.
- Jim Kirksey (Schlumberger) described approaches to improving well integrity at the time of construction. He pointed out there are API (RP 65) and NORSOK standards to guide this effort. Key factors to address include mud removal, centralization, and fluid rheology.
- Ron Sweatman (Baker Hughes) described recent work on the effects that temperature can have on inducing abnormal pressures in the well, potentially resulting in unforeseen problems with fluid balance.
- Eduardo Granados (GeothermEx) provided a very valuable perspective on well integrity in geothermal systems that hadn't been considered by the Wellbore Integrity group before. He described differences in integrity requirements such as the need to cement to surface in all cases and monthly ultrasonic inspections of casing integrity.
- Wes Peck (Energy and Environmental Research Center) developed an analysis of wellbore integrity in the Williston Basin. He used the Watson and Bachu methodology to develop risk metrics for 846 wells.
- Linda Luquot (CINME) conducted an experimental study of CO<sub>2</sub>-saturated brine through fractured cement samples. She observed that high flow rates led to the development of a silica gel residue that had the potential to reduce permeability; low flow rates led to calcite precipitation and permeability reduction; while intermediate rates developed leached zones and increased permeability.
- Pascal Audiane (BRGM, French geological survey) discussed a new field experiment in Mont Terri, Switzerland in which a shaft was constructed within a tunnel in which leakage processes are to be studied in an actual borehole-casing-cement system. The study will investigate thermal effects, among other factors, on cement and the possible development of microannuli.
- Axel Bois (CurisTec) described geomechanical modeling of the wellbore environment, including an interesting discussion of the importance of understanding the initial stress state of cement. He discussed the importance of phenomena such as varying failure regimes, pore collapse, cement

shrinkage, and creep. A discussion followed on the capacity for self-healing (collapse) of microannuli.

- George King (Apache Corp.) examined factors governing wellbore integrity failure. He distinguished between barrier failure, involving a component of the wellbore system, and integrity failure involving leakage of fluids out of the well into the environment. He summarized several studies on rates of integrity failure and argued that hydraulic fracturing is not more prone to failure than conventional wells. He emphasized the difficulty in drawing conclusions on well behavior across decades (where practices change) and regions (where geology is different).
- Andrew Duguid (Schlumberger) related experiences from a field study of the quality of cement/casing in wells in Wyoming that were aged but not exposed to CO<sub>2</sub>. He conducted vertical interference tests, finding effective leakage rates between 25 and 170 mD, but much higher than the intrinsic permeability of cement recovered from the well at 0.01-5 mD.
- John Hull (HiFi Engineering) described new technologies in acoustic monitoring of leakage in wellbore systems.
- Steve Bryant (University of Texas) analyzed sustained casing pressure data from the Gulf of Mexico and Alberta to develop estimates of effective permeability of well leakage. He found that leak rates were sufficiently low such that the impact was of order 1 tonne/year.
- Chris Hawkes (University of Saskatchewan) described the wellbore integrity program from the Weyburn Project. The work included a field study and sampling of a well with about 5 years of potential CO<sub>2</sub> exposure. A vertical interference test was run and found very low permeability in the 10s of μD. They used a novel drilling device to obtain 3/8"-diameter core but the samples were very difficult to extract.
- Mary Kang (Princeton University) discussed monitoring studies of methane emissions from abandoned/orphaned wells in Pennsylvania. Many wells had measurable emissions.
- Karlis Muehlenbachs (University of Alberta) described research on isotopic fractionation processes as a means of diagnosing sources of gas migration. A large fraction of the leaking gas studied was from sources much shallower than the reservoir.
- Al Cunningham (Montana State University) is using biomineralization as a remediation approach. He described experiments showing impressive degrees of calcium carbonate precipitation generated by when calcium-bearing nutrients were supplied to bacteria. He also described an upcoming field campaign in which he will attempt to decrease permeability in a hydraulic fractured well.
- Jim Kirksey (Schlumberger) gave an overview of commonly used well remediation methods based on cement squeezes and other materials.